CALIFORNIA GEOTHERMAL RESOURCES

IN SUPPORT OF THE 2005 INTEGRATED ENERGY POLICY REPORT

Elaine Sison-Lebrilla
Valentino Tiangco
Research and Development Office
Energy Research and Development Division
California Energy Commission

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Abstract

California has the largest geothermal production and potential of any state in the nation with an installed gross capacity of 1,870 Megawatts (MW) and an estimated potential generation capacity of 4,732 MW. Even though geothermal electricity generation has declined in the past decade, an estimated 2,862 MW of generating capacity from geothermal may be available for development. Certain drivers have emerged to encourage the development of geothermal resources. The California Legislature adopted the Renewable Portfolio Standard (RPS); the federal government has made a production tax credit (PTC) available to new geothermal generation facilities. Geothermal is a base load resource, and developing currently untapped geothermal resources can contribute significantly to the goals of the RPS.

Keywords
Geothermal, dry steam resource, liquid dominated resource

Introduction

California has a tremendous supply of renewable resources that can be harnessed to provide clean and naturally replenishing electricity supplies for the state. Currently, renewable resources provide approximately eleven percent of the state's electricity mix.[1] California's Renewable Portfolio Standard (RPS) established in 2002 by Senate Bill 1078 (SB1078, Sher, Chapter 516, Statutes of 2002) requires electricity providers to procure at least one percent of their electricity supplies from renewable resources so as to achieve a twenty percent renewable mix by no later than 2017. More recently, the California Energy Commission, the California Public Utilities Commission and the California Power Authority approved the Energy Action Plan (EAP), accelerating the twenty-percent target date to 2010.[2]

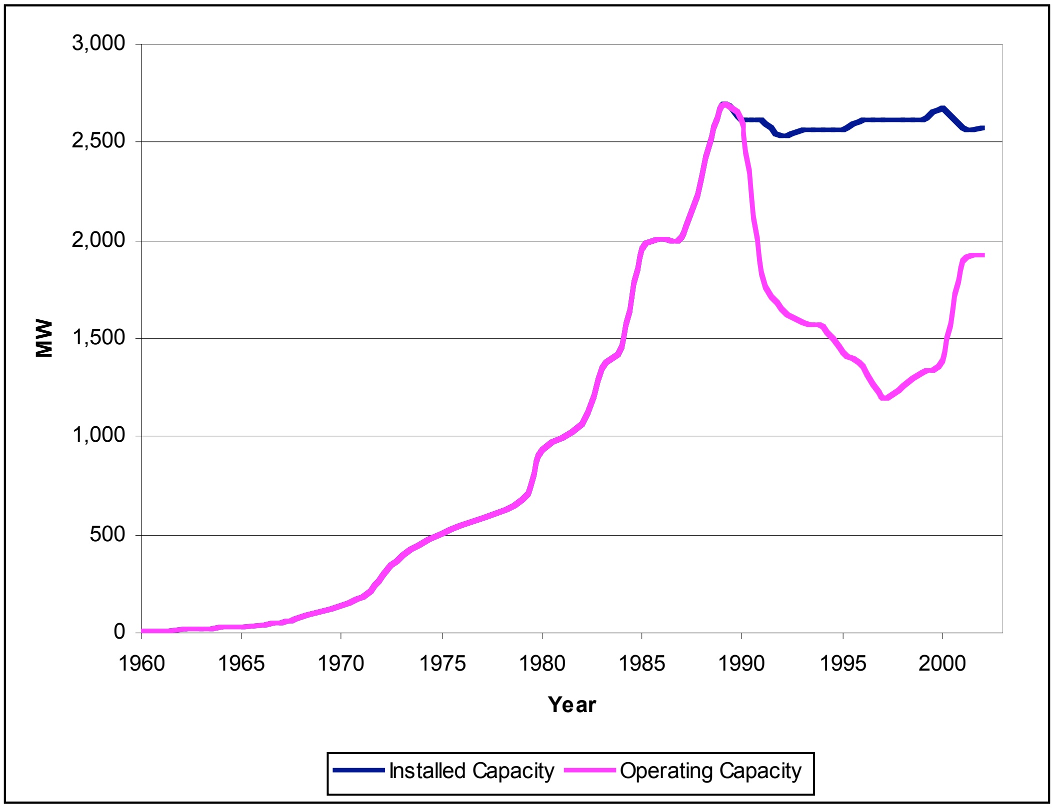
The purpose of this white paper is to provide estimates of the geothermal resources located within California and potentially available for use in meeting the RPS and EAP goals. Estimates are provided on the "technical" potential (i.e., unconstrained by economic or environmental requirements). This information updates and expands upon resource information provided in the Renewable Resources Development Report of 2003.[3]

Short History Of Geothermal Development In California

Currently, California's geothermal generating capacity is approximately 1,870 MW from both dry steam and liquid dominated resources (see Table 1). In the state, 46 geothermal power plants are widely dispersed from north to south (see Figure 2). While most development has occurred in The Geysers, the Salton Sea and Coso Known Geothermal Resource Areas (KGRA) both have considerable installed capacity.

Over the past decade, geothermal resource use stagnated considerably and the geothermal industry has retrenched. As illustrated in Figure 1, installed or nameplate capacity peaked in 1989 at 2,686 MW. Since then, both installed and operating capacity have declined due to plant retirement, and more importantly, operating capacity has declined due to the reduction in steam flow at The Geysers. This decline, over 1,300 MW in 1998 at the nadir and approximately 640 MW in 2002, has had serious ramifications both to the geothermal community as well as stable power supplies to Californians. In the following sections the discussion focuses on the individual fields and status.

Figure 1
California Installed and Operating Geothermal Capacity[4]
(1960-2003)



A Dry Resource-The Geysers

In the late 1950's, companies such as Union Oil Company of California (Unocal), Magma Energy Company and Thermal Power Company initiated full scale commercial development of vapor dominated geothermal at The Geysers. These companies produced steam to the Pacific Gas and Electric Company (PG&E) electrical power generation grid. Since then, The Geysers has developed into the world's largest dry steam resource with almost 2,000 MW (1989) of installed electrical generating capacity and is the only dry steam field that is commercially developed in the nation. The Geysers geothermal field reached maximum steam production of 1,866 MW in 1988 and today, The Geysers retains a peak capability of nearly 1,000 MW.

Since the mid 1980s, The Geysers reservoir has exhibited the effects of heavy steam withdrawal. Steam pressure, particularly in the central part of the reservoir, has dropped much faster than was originally expected. In many existing wells, steam pressure has declined from the initial 500 pounds per square inch (psi) in 1960 to less than 200 psi, shortening the wells' useful life and hastening the need for make up wells. This condition is due to cumulative over production. In many instances, the additional supply of steam by new make up wells has proven to be insufficient to maintain the original steam output. Also, many of the steam developers are encountering production interference. That is, steam that would otherwise be produced from an existing well is diverted to a new well.

The steam production decline demonstrates the importance of increased water injection to maintain reservoir pressure. While continuing research is helping to determine the best methods for water injection, mitigation efforts such as the Santa Rosa and Southeast Geysers pipeline projects to augment fluid injection to offset production declines have been implemented. Other activities implemented include modifications to plant operations for increasing efficiency. In addition, the older, less efficient power plants have been suspended, and steam rerouted to newer and more efficient plants. Plant operators have installed new turbines designed to operate at lower turbine inlet pressures and modified the design and operations of existing turbines, condensers, and gas handling systems for low-load and cycling. These changes may extend the life of the resource, but come at a higher cost.

Geothermal resources developments are now planned with more caution than before, to avoid a scenario similar to The Geysers. The competition between steam producers and plant operators has eased as ownership of The Geysers has been consolidated and auction strategies have changed. Reservoir management activities are being implemented such as further spacing of production and injection wells, as well as monitoring water resources for flow, quantity, chemistry, and tendencies toward brine and scaling. As a result, binary and liquid dominated flash extraction systems are the only ones installed today.

Liquid Dominated Geothermal Resources

Geothermal exploration of liquid dominated resources in California began in 1967, when both Unocal and Morton Salt Company deployed small, experimental geothermal turbines operating at the Salton Sea field. However, problems with silica scaling and high salt concentrations prevented the commercial development of the resource then. In developing liquid dominated resources during the 1970's, developers had to consider the degree of risk, greater capital costs, an adverse regulatory climate, and the relative immaturity of the exploration, drilling, and production technology, which impeded the development of liquid dominated resources. These impediments were mitigated significantly when the federal and state government responded to the oil crisis of 1973.

The development of liquid dominated resources was further facilitated in 1975, when the U.S. Geological Survey (USGS) concluded a nation-wide geothermal resource assessment.[5] The USGS assessment document was instrumental in expanding interest in developing liquid dominated resources in the Southwestern states.

A liquid dominated geothermal resource was developed in November 1979 for a power generation plant, at the East Mesa field in Imperial County, which consisted of a binary application using isobutane as the secondary working fluid to turn out 13.4 MW of electrical power.

In June 1980, Southern California Edison (SCE) began operating a 10 MW experimental power plant at the Brawley geothermal field with steam produced by Unocal. However, after a few years of operation, SCE and Unocal ceased further development of the field due to corrosion, reservoir uncertainties, and the high salinity brines.

In June 1982, Unocal initiated electrical power generation at the Salton Sea geothermal resource from its 12 MW plant. In 1982, Unocal added two additional generation units for a total gross electrical generation of 83 MW.

In late 1985, Magma Power Company (Magma) began continuous production from their first 40 MW power plant at the Salton Sea field. Within a couple years, Magma added 3 more generating units that brought their total to 145 MW. CalEnergy Corporation (CalEnergy) bought out Unocal's and Magma's operations at the Salton Sea. Today, the entire Salton Sea field operation consists of 8 power plants with 288 MW capacity.

CalEnergy and Calpine Corporation (Calpine) planned developments in the Glass Mountain KGRA but were initially halted due to permitting issues related to destruction/disturbance of habitat and conflicts with Native American spiritual beliefs. Both projects eventually received permitting approval from the Bureau of Land Management (BLM) to proceed to the development stage.

The California Energy Commission awarded Calpine $1,108,000 in June 2001 to drill an exploration well in the Fourmile Hill area of the Glass Mountain KGRA. The project was completed as of June 2003, but Calpine encountered a geothermal resource at a temperature of 411°Farhenheit (F) at a depth of 6,360 feet with low permeability. The well can only produce 22 kilo pound per hour (kph) steam and 105 kph total mass flow at a wellhead pressure of 14 pounds per square inch gage (psig) which is insufficient to justify developing the 49 MW project. In addition, legal action against this project has been filed by the Earthjustice Environmental Law Clinic (Earthjustice) at Stanford.[6] The status of this project is uncertain.

In October 2001, Calpine acquired all of CalEnergy's interests in Glass Mountain KGRA, including Telephone Flat. In May 2003, the Department of the Interior issued a site license authorizing the operation of a 48 MW geothermal power plant in Telephone Flat. Calpine has all major permits to develop a geothermal power plant at the Telephone Flat Prospect. However, current legal action by Earthjustice and the Save Medicine Lake Coalition leaves the status of this project uncertain.[7]

Figure 2 Known Geothermal Resource Areas

Source: California Energy Commission

Table 1 Location of California Geothermal Power Plants and Capacity

Geothermal Resource Area	County	Existing Gross MW
East Mesa	Imperial	73.2
Heber	Imperial	100
Salton Sea (including Westmoreland)	Imperial	350
	Imperial Total:	523.2
Coso Hot Springs	Inyo	300
Geysers (Lake & Sonoma Counties)	Sonoma/Lake	1000
	The Geysers Total:	1000
Honey Lake (Wendel-Amedee)	Lassen	6.4
Long Valley (mono- Long Valley) Mammoth Pacific Plants	Mono	40
Total:		**1870**

Source: "*New Geothermal Site Identification and Quantification*" by GeothermEx Corporation

Geothermal Resource Assessment

In July 2002, the Energy Commission executed a Public Interest Energy Research Program (PIER) contract with Hetch Hetchy Water and the Power Division of the San Francisco Public Utilities Commission (Hetch Hetchy/SFPUC) to fund studies and projects related to renewable energy. GeothermEx, Inc. (GeothermEx) was retained by Hetch Hetchy/SFPUC to provide a geothermal resource assessment for California and western Nevada. This section summarizes the findings of GeothermEx on the resource assessment for California[8].

GeothermEx used prior research, exploration, and development results that are available in the public domain. They also used data and information released by some developers into the public domain for this study. Three baseline conditions were used to determine the geothermal resource areas included in this assessment: geographic location, resource temperature, and evidence of a discrete resource. In California, 22 geothermal resource areas were included in the assessment.

Among the various geothermal resource areas, the amount and quality of technical data are extremely variable. Because of this, a uniform set of required resource criteria needed to be quantified to determine commercial feasibility for each resource area. For each selected reservoir, values for the following criteria were obtained or reasonably estimated: temperature, area, thickness, porosity, and resource recovery factor.

To better capture the uncertainty of each resource, minimum, most likely and maximum values were used for each criterion. These values were then used in probabilistic simulation, based on Monte Carlo random-number sampling, to calculate estimated generation capacity based on the accessible heat in place at the resource area. Because the generation capacity is estimated based on calculated heat in place, there is no guarantee that sufficient permeability exists to allow commercial production for those resources where little or no drilling has occurred.

For the 22 California resource areas, the total estimated most-likely generation capacity was calculated to be approximately 4,732 MW. The total generation capacity, minus the installed gross capacity of existing generation, was 2,862 MW. Table 2 reflects the estimated generation capacity for each resource area, grouped by geographical area and county.

Despite the steam production decline mentioned earlier, The Geysers has potentially 400 MW of most-likely generation capacity available. The total proven reservoir at The Geysers is nearly 40 square miles, as determined by the extensive shallow and deep drilling in the region. For this area, there is a portion of approximately 10 square miles, which has never been developed for continuous steam supply. Lying between the Aidlin project area to the northwest and the areas of units 5-6, 7-8 and 11 to the southeast, these 10 square miles comprises about 25% of the 40 square miles total proven area. In addition, about 2 square miles in the northeastern of the field (within the proven reservoir area) remained untapped at the former Bottle Rock project and contiguous area to the southeast. In these areas, a reasonable estimate of average installed capacity is 33 MW per square mile. Therefore, the unutilized 12 square miles should be able to support about 400 MW under the right economic conditions.

Recent Geothermal Development Trends And Future Direction

This section focuses on trends currently observed in the geothermal industry; these trends are differentiated by: (1) technology, (2) environmental, (3) institutional, and (4) economic considerations.

Table 2: Most-Likely (MLK) Geothermal Resource Capacity

Geothermal Resource Area	County	MLK MW	Existing Gross MW	MLK-Existing MW
Brawley (North)	Imperial	135	0	135
Brawley (East)	Imperial	129	0	129
Brawley (South)	Imperial	62	0	62
Dunes	Imperial	11	0	11
East Mesa	Imperial	148	73.2	74.8
Glamis	Imperial	6.4	0	6.4
Heber	Imperial	142	100	42
Mount Signal	Imperial	19	0	19
Niland	Imperial	76	0	76
Salton Sea (including Westmoreland)	Imperial	1750	350	1400
Superstition Mountain	Imperial	9.5	0	9.5
	Imperial Total:	2487.9	523.2	1964.7
Coso Hot Springs	Inyo	355	300	55
Sulfur Bank Field, Clear Lake Area	Lake	43	0	43
Geysers [Lake & Sonoma Counties]	Sonoma	1400	1000	400
Calistoga	Napa	25	0	25
	The Geysers Total:	1468	1000	468
Honey Lake (Wendel-Amedee)	Lassen	8.3	6.4	1.9
Lake City/ Surprise Valley	Modoc	37	0	37
Long Valley (mono- Long Valley) Mammoth Pacific Plants	Mono	111	40	71
Randsburg	San Bernardino/ Kern	48	0	48
Medicine Lake (Fourmile Hill)	Siskiyou	36	0	36
Medicine Lake (Telephone Flat)	Siskiyou	175	0	175
Sespe Hot Springs	Ventura	5.3	0	5.3
Total:		**4732**	**1870**	**2862**

Source: "*New Geothermal Site Identification and Quantification*" by GeothermEx Corporation

Technology

Recent and forecasted trends for geothermal technology development may be characterized within the following four classifications: (1) resource exploration, (2) resource development and completion, (3) drilling, and (4) power generation technology.

Resource Exploration

In 2004, the USGS began to categorize new geothermal resources, principally in the Great Basin of the western United States. This work will update the existing resource assessment completed in the 1980's. Because of the inherent difficulty in assessing geothermal potential, this work is likely to be important to further define the possibilities for new geothermal development.

Initiated in 2000, Geothermal Resource Exploration and Definition (GRED) Program is a cooperative Department of Energy (DOE)/industry effort to find, evaluate, and define additional geothermal resources throughout the western United States. To help mitigate a portion of the initial risk associated with the exploration and definition of geothermal resources, DOE provides up to 50% cost sharing. The DOE and its laboratories also provide technical oversight and monitoring.

Improvements and trends in resource exploration can be grouped as follows:

- Continue to develop of geophysical survey methods to identify those with the most robust signatures.
- Identify the advantages and limitations of imaging technologies (e.g., infra-red, SAR, ground penetrating radar) for exploration.
- Identify naturally occurring tracers that provide information on the time scale of interest (1,000's years).
- Integrate reservoir simulation with geophysical methods to predict the exploration signature of geothermal fields.
- Develop techniques to locate subsurface fracture zones.

Progress continues in applying micro earthquake seismology to identify active fractures. Seismic reflection and refraction techniques are now capable of providing sharper structural resolution, especially in rocks with the chaotic, non-bedded, and poorly bedded characteristics typical of geothermal reservoirs. These improvements have helped to reduce exploration time and costs, and the drilling risk.[9]

Resource Development and Completion

This element addresses the need to better understand subsurface conditions and develop techniques to modify the subsurface to recover energy from reservoirs lacking sufficient natural flow for economic development. Economically viable geothermal systems have both sufficient heat and permeability. Engineered geothermal systems (EGS) are transformed geothermal resources which had sufficient heat, but lacked adequate rock matrix permeability and/or natural reservoir fluids to transport the heat to the surface in economic quantities. The U.S. was an early leader in developing technology for engineered geothermal systems (i.e. the Hot Dry Rock effort at Los Alamos / Fenton Hill). During the 1990s, the Japanese program made significant advances, while the European community continues to develop their hot dry rock project located in France.

Progress continues to be made in the following reservoir development areas:

- Increase fundamental understanding of geothermal fields,
- Develop improved understanding of how to sustain production from hydrothermal systems and enhanced and engineered geothermal systems, and
- Demonstrate tools for designing and predicting the performance of engineered geothermal systems.

Reservoir simulators are being coupled with geophysical models to assist in developing geothermal system models used to frame exploration for new geothermal systems. Integrating reservoir simulators to geochemical and geomechanical models will enable future design and operation of engineered geothermal systems.

Drilling

Geothermal drilling is difficult because rocks are hard, abrasive, fractured, and, by definition, hot. Formation fluids are often highly corrosive and usually underpressured (i.e., pore pressure is less than an equivalent column of water). These harsh conditions mean that many of the tools used to reduce cost in oil and gas drilling cannot be used in geothermal reservoirs. Also, the requirement for geothermal wells to produce large volumes of fluid means that geothermal wells are larger in diameter than equivalent oil and gas wells of the same depth. All of these factors drive the cost of typical geothermal wells much higher than oil and gas wells of comparable depth.

For the near term, the development of geothermal drilling technology will continue to address the following elements:

- High temperature electronics. Batteries, components, printed circuit boards and monitoring technology with fiber optics and high temperature tools will continue to be developed for the harsh geothermal environment. This “segment” will benefit from concurrent development of instrumentation for jet engines.

- Rock reduction. Considerable advances have been made in cutter technology, bit and drillstring dynamics, and bit hydraulics. New computer simulation techniques and advanced materials are likely to foster greater development in this area.

- Diagnostics-while-drilling. The advances in electronics, sensors, and data management continue to flow into the geothermal drilling industry. Continued improvements in diagnostics will foster greater penetration rates and shorter downtimes.

- Wellbore integrity. Lost circulation zones, cross-flow control, cementing and well completion continue to present challenges to drillers. Improved twin-streaming sodium silicate and cement plugs will see increased utilization. R&D efforts on trimie pipe and reverse circulation primary cementing will foster “trouble free” drilling and cementing.

Power Generation Technology

Over the past decade, few geothermal plants have been built. However, discernible trends exist that are affecting electricity production including the following:

- The advent of low-temperature power plants has spurred a new interest in developing more efficient cycles such as the Kalina cycle.[10]
- The most severe challenge to improving the cycle efficiency for either a steam or a binary cycle is on the low-temperature side – the rejection of heat to the ambient environment. This requires improvements in heat exchangers used as condensers. The challenge is to use fluid flow to take advantage of opportunities to disrupt and renew boundary layers to enhance transfer rates with no additional parasitic energy losses.

- Some brines are quite corrosive, particularly higher temperature brines. These present a challenge for innovative coatings and linings that have sufficient protection to allow the use of inexpensive base materials such as carbon steel while providing the benefits of low initial cost and long service life.

- Many geothermal source locations tend to be in arid areas, necessitating the use of air-cooled heat exchangers for heat rejection. This means an extreme sensitivity to ambient air temperature, especially in the summer.

This may require innovative design and operating techniques for hybrid condensers.

- Geothermal operators will continue to adopt monitoring technology from other power plants to increase efficiency of operations.

- The costs and performance of geothermal plants is poorly documented and not universally understood as only a small number of significant plants have been built within the U.S. for the last decade. This makes it difficult to compare alternatives.

Environmental Effects From Geothermal Developments

While geothermal is generally considered among the most environmentally preferred energy sources, power plants can emit trace amounts of heavy metals. Over the next several years, plant operators are likely to install activated carbon systems to remove metals emissions such as mercury.

A majority of flashed steam plants in California have been built in the Imperial Valley, where the problems associated with waste disposal can be reduced by recovering various minerals from the spent geothermal brine before the fluid is injected into the ground. Studies by CalEnergy have shown that mineral (i.e. zinc, silica and manganese) recovery to be economical. CalEnergy has made substantial progress in reducing waste disposal cost and more importantly been able to turn a waste product into a revenue-enhancing venture through the extraction of zinc. If silica and manganese can also be extracted, CalEnergy estimates that these combined waste reduction operations may reduce the amount of wastes generated by 95%.

Because of the strict sitting regulations, developer's typically plan to minimize habit disturbance. Directional drilling will continue to be a preferred technology because of the lessened impact associated with well pad siting. Drillers will incorporate advanced monitoring systems to minimize fluid leakage during drilling.

Institutional[11]

Federal legislation has been proposed to "streamline" the often time consuming and duplicative processes for geothermal power plant siting, development, and operation. Specifically, federal and state agencies are now developing administrative procedures for processing geothermal lease applications, including lines of authority, steps in application processing, and timeframes for application processing.

Specific to the US National Forests, efforts are underway to better define and classify the known geothermal resources on USFS lands as well as to develop plans for leasing the land for geothermal production. Further, web-enabled data retrieval systems are being implemented to track lease and permit applications and requests.

Because of the vast nature of military land jurisdiction, coupled with the Federal requirement for 2.5% of electricity purchases to come from renewable sources, it is likely there will be increased exploration and development of geothermal resources on military lands. Coupling the development of military resources to the Geothermal Steam Act provisions will allow for common regulatory or siting considerations for developers.

In 2002, the Governor signed the Renewable Portfolio Standard (RPS) (SB 1078, Sher, Chapter 516, Statues of 2002. This standard requires an annual increase in renewable generation equivalent to at least 1% of sales, with an aggregate goal of 20% by 2017. In the second quarter of 2003, the California Energy Commission, the Public Utilities Commission (CPUC), and the Consumer Power and Conservation Financing Authority (called the CPA - which is now defunct) adopted the Energy Action Plan (EAP) that identified specific goals and actions to eliminated energy outages and excessive price spikes in electricity or natural gas. The EAP recommends aggressively implementing the RPS, with the intent of achieving the 20% goal by 2010[11].

Economic

The Energy Policy Act of 1992 created a PTC to produce electricity from renewable energy sources. Codified as Section 45 of the Internal Revenue Code, certain renewable facilities (mostly wind technologies) qualify for a production tax credit that initially provided 1.5 centers per kilowatt-hour.

In October 22, 2204, H.R. 4520, the “American Jobs Creation Act of 2004”, was signed into law, expanding the availability of the PTC include geothermal and other renewable resources. Under the terms of this new law, the PTC is 1.8¢/kWh (1.5¢/kWh adjusted for inflation) for a new facility's first five years of operation. The credit will also be allowed against a company's alternative minimum tax. However, to qualify for the credit, new plants must be up and running by the end of 2005. Efforts are currently undertaken by the geothermal industry to have this deadline extended.

Presently, the calculation and payment of royalties on leased Federal lands is a complex process. Recently proposed Federal legislation seeks to reduce the complexity of the royalty payment process and return the funds to the state and county. As of late 2004, the US Department of Interior (DOI) is planning a new initiative to simplify and improve the geothermal royalty system. The DOI has put together a Geothermal Royalty Review Committee to examine alternative approaches to geothermal royalties. This committee held a public meeting in late January 2005 to get input from interested parties.

Summary

Geothermal energy provides significant benefits in terms of improved air quality, increased diversity in electric energy sources, local and state revenues, and employment. California has the largest geothermal installed capacity in the country with approximately 1,900 MW. In addition, California has the potential to produce an estimated additional 2,862 MW from resource areas such as Coso Hot Springs, Imperial Valley, Glass Mountain, and Mono/Long Valley. Imperial County has 11 KGRAs including Brawley, Salton Sea, and East Mesa, and has the largest potential resource base within the state at over 2,400 MW. Cal Energy applied and received a permit to construct a 185 MW power plant in the Salton Sea KGRA. They anticipate completing construction, at the earliest, in 2006. With the RPS and the PTC in place, geothermal development is poised to increase dramatically within the next decade.

Endnotes

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